PHYSICAL PRINCIPLE OF USING TUBES FOR VOICE THERAPY METHODS DEMONSTRATED BY EXPERIMENTAL MODEL OF PHONATION

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INTRODUCTION

Phonation through a tube either with the distal end in air or in water is widely used for voice training and therapy. This study investigates principles of both methods by combining results from computer modelling [1] and physical modelling [2,3]. The aim is to study whether or not the principle is the same.

METHODS

The physical model consists of 1:1 scaled silicon vocal fold (VF) replica and a plexiglass tube representing the vocal tract (VT) for [u:] vowel. The VT was prolonged by the glass resonance tube (27 cm length, 7.8 mm inner diameter) with the other end in air or submerged 10 cm below water surface. The airflow rate was varied in the range *Q*=0.06-0.09 L/s. Glottal area (*GA*) variation was registered with high speed camera. Formant frequencies were measured from the acoustic signal in the oral cavity.

RESULTS

In the experiment, the first formant frequency F1=305-330 Hz for [u:] decreased to F1=100-125 Hz for phonation through the tube into air and to F1=29-30 Hz for phonation through the tube into water. The computed frequencies are compared in Table 1 with the frequencies F1, the water bubbling frequency Fb and the fundamental frequencies fo measured in the model.

Figure 1 shows difference between vowel and tube phonations when studying the work done by airflow during the VFs self-sustained vibration. The loops constructed from transglottic pressure Ptrans(t) and GA(t) waveforms for tube phonation into air and water are similar, but for water not exactly periodic due to irregularities caused by bubbling.

Table 1: Computed acoustic resonance frequencies considering hard walls of the VT model, and the measured formant frequencies F1, for phonation on vowel [u:] and on [u:] with the VT prolonged by the resonance tube with the distal end in air and in water.

Phonation type	f0 [Hz]	Fb [Hz]	F1 [Hz]
Vowel [u:]			
computation	/	/	333
experiment	91-93	/	305-330
Resonance tube in air			
computation	/	/	97
experiment	93–94	/	100-125
Resonance tube in water			
computation	/	/	28
experiment	89–91	21–22	29–30

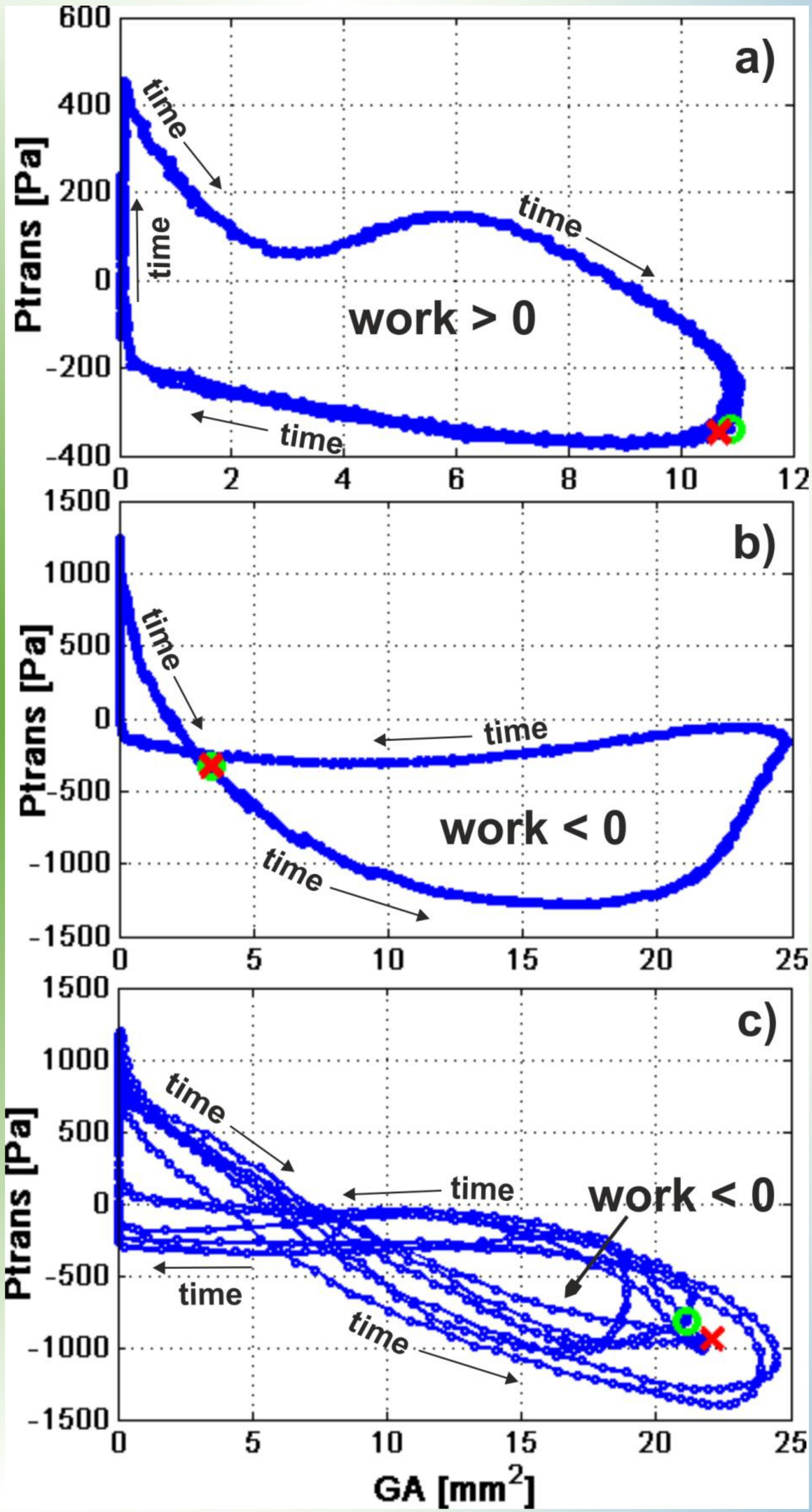

Figure 1: Examples of the loops Ptrans(t) vs. GA(t) measured during 6 periods of the VFs self-oscillation for phonation through: a) the VT, b) the VT+tube into air, c) the VT+tube into 10 cm water (Q=0.09 L/s).

For phonation into air, f0 excites the acoustic resonance at F1, and for phonation into water, the water bubbling frequency excites a low frequency resonance which is caused by yielding walls of VT in humans.

DISCUSSION AND CONCLUSION

The basic principle in vocal exercises with a resonance tube with the distal end in air or in water is the same. In both voice therapy methods, part of the airflow energy required for phonation is substituted by the acoustic energy, utilizing the first acoustic resonance. Thus, less flow energy is needed to deliver the self-sustained vibration of the vocal folds.

REFERENCES

[1] Horáček *et al*, Biomed Signal Proc and Control 37: 39-49, 2017.

[2] Horáček *et al*, J Voice 33(4): 490-496, 2019.

[3] Horáček *et al*, J Speech, Lang, and Hear Res 62: 2227–2244, 2019.